THE USE OF UREA AS A PROTEIN SUPPLEMENT FOR RUMINANTS

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INTRODUCTION

To supply sufficient protein for growing and lactating animals has been one of the major problems of the livestock producer. With the possible exception of leguminous crops, practically all of the common livestock feeds supply insufficient protein to satisfy the needs for normal growth and high milk production. In the past, protein supplements have been of plant origin such as linseed meal or of animal origin such as tankage. During the war the source and distribution of these supplemental feeds have been affected and scientists have sought substitutes that could be utilized during periods of shortages.

The demand for explosives during the present war has resulted in the building of several plants for the manufacture of ammonia. Unless new uses for ammonia can be found these plants will have to be discarded after the war. Urea can readily be made in these plants and it is already known that urea has a place in the manufacture of synthetics and, as will be pointed out later, it has a possible use as a feed for ruminants.

Urea may be made synthetically from dry carbon dioxide (CO_2) and dry ammonia (NH_3) thus:

$$CO_2 + NH_3 \longrightarrow CO.NH_2.OH$$
$$+ NH_3 \longrightarrow CO.NH_2.ONH_4$$
$$- H_2O \longrightarrow CO:(NH_2)_2$$

If urea can be utilized by livestock it may prove to be an economical source of protein as well as a means of assisting in the conversion of wartime factories to peace-time needs.

In the fall of 1943 the Consolidated Mining and Smelting Company of Trail, B.C. provided a fund to the University of Alberta to assist in a research project in which the possible value of urea as a protein supplement for ruminants could be investigated. The arrangement was that the University should supply the experimental animals and conduct a feeding test for two winters.

PREVIOUS LITERATURE

Before going into detail with regard to the feeding trials conducted at the University of Alberta, a brief review will be given of urea feeding experiments that have been conducted at other institutions.

Feeding Trials

Hart et al (3) mention in the introduction to some of their work that experiments involving the feeding of simple nitrogenous substances to ruminants were first carried out in Europe during the last war in an attempt to get around the shortage of usual sources of protein. They state, however, that the European experiments gave negative results, and they attributed this to the fact that the tests were only of short duration. Feeling that conclusive results could be obtained only by the use of long-term feeding experiments, they initiated several tests with this in mind.

Their first experiment (3) was designed to test the effect of feeding different levels of urea and ammonium bicarbonate on growth rate and meat quality of calves.

Six grade Holstein heifers ranging in weight from 250 lb. to 290 lb. were selected. A low protein basal ration (5.38%) was purposely designed as follows:

Yellow corn	20.0
Ground timothy hay	47.5
Starch	24.0
Molasses	10.0
Steamed bonemeal	2.0
Salt	1.0
Cod liver oil	0.5

One calf received the basal ration and acted as the check, while another calf had the basal ration supplemented with casein as a means of comparing the value of urea and ammonium bicarbonate with casein as a source of protein. The

rations for the different calves are shown in tabular form:

TABLE I

Rations fed to the different calves

Calf	Protein	Pounds of supplement per 100 lb. ration	% protein 6.25 x N	% N from supplement
1	Basal alone	--	5.38	
2	+ urea	1.4	9.49	43
3	+ urea	2.8	13.70	61
4	+ urea	4.3	17.64	70
5	+ $(NH_3)HCO_3$	11.1	17.04	69
6	+ casein	11.0	15.52	66

With the exception of No.1 the calves received the rations as shown above for a period of 20 weeks. The basal ration seems to have been enough for the maintenance of weight only. For 12 weeks the weight of calf No.1 remained stationary, the appearance was listless and apathetic, the coat was staring and appetite was very poor, the whole day often being required for the consumption of the ration. At the end of 12 weeks, No.1 was switched to the ration being fed to No.2 (1.4% urea) at which time an almost phenomenal improvement took place in the calf's condition. Within two days its appetite had improved, a more healthy appearance became apparent, a gain of 11 pounds was shown within one week, and gains continued to be excellent to the end of the feeding trial. In the final analysis, calves No.1, No.2, and No.6 were found to have made the best gains. The other three calves which received higher levels of nitrogen

did not make such satisfactory gains. They were subject to diuresis and showed some evidence of degeneration of the kidneys, indicating that the higher levels of feeding nitrogenous substances were not satisfactory.

Later, these animals were slaughtered and analyses of the tissues of different cuts were made. These analyses showed no significant difference in the composition of the tissues from the urea-fed and casein-fed animals.

This feeding trial shows definitely that calves can use the nitrogen of urea and ammonium bicarbonate for purposes of growth. While the experiment did not indicate a definite toxic level for these nitrogenous compounds, it was shown that, if more than 60% of the nitrogen of the ration was fed in the form of urea or ammonium bicarbonate, lesions would become apparent in the kidneys.

Rupel et al (8) at Wisconsin compared the effect of urea and linseed meal on milk production and body weight when they were fed to lactating dairy cows during a full lactation period. Three lots of 15 cows each were used, three rations being fed as follows:

	Basal	Linseed meal	Urea
Ground yellow corn	49.0	32.0	47.5
Ground oats	49.0	32.0	47.5
Linseed meal		34.0	
Urea			3.0
Bonemeal	1.0		1.0
Ground limestone		1.0	
Iodized salt	1.0	1.0	1.0
% protein	10	18	18

Results of this investigation, indicating the total 4% F.C.M. produced and the gains in body weight during a full lactation period, were as follows:

Ration	4% F.C.M., lb.	Gains, lb.
Basal	6675	25
Linseed meal	7790	112
Urea	7690	102

The authors state that the difference in milk production and gains in body weight were not statistically significant between lots receiving urea and linseed meal. The lot fed the basal ration was significantly lower than the lots fed urea and linseed meal, in both body weight and production of fat-corrected milk.

These authors state that, with the price of corn and oats at $30.00 per ton, urea at $70.00, and linseed meal at $47.00, they realized a saving of $4.40 per ton of concentrate by the use of urea as compared with linseed meal. We may conclude from this test that urea was equal to linseed meal in the production of milk and the maintenance of body weight and, furthermore, that a substantial financial saving was made by its use.

Archibald (1), at the Massachusetts State College, used the following rations with 24 Holstein cows over a period of three years, to compare the value of standard protein supplements and urea as sources of protein for lactating cows. The rations are shown in Table II.

TABLE II

Formulas of grain mixtures

Ingredient	Ration, lb.		
	Regular	Urea	Control
Hominy feed	600	600	660
Ground oats	400	600	600
Wheat bran	500	200	200
Corn gluten feed	200	-	-
Soybean meal	100	-	-
Cottonseed meal	200	-	-
Cornstarch	-	540	540
Urea	-	60	-
Salt	20	20	20
Bone meal	-	40	40
Vitamin A concentrate	5	5	5

It may be noted that cornstarch was used to make up the loss in energy caused by omitting the protein concentrates included in the regular ration. In the urea ration the urea supplied 42% of the nitrogen of the grain mixture or 25% of the nitrogen of the total ration.

The results of the experiment indicated that, in the production of fat-corrected milk, the length of lactation and dry periods, reproduction, and flavor of the milk produced, the differences between the groups on the "regular" and "urea" were not significant. The "control" ration, however, was found to be inadequate to support milk production at a normal level.

Archibald sums up the results of this work as follows: "Results showed that considerable use was made of the urea, although it was not quite on a par for maintenance and milk production with the standard protein concentrates."

Wise et al (13) conducted a feeding trial in which lactating cows were fed a corn silage to which 10 pounds of urea per ton had been added during ensiling. Their results indicate that the urea-treated silage was not as palatable as the untreated. Cows receiving the urea-treated silage consumed 52.5 pounds per day, whereas those receiving the untreated consumed 60 pounds per day. They noted that the carotene content of the silage was lowered from 36.58 micrograms per gram to 11.50 micrograms per gram by the addition of urea. This was reflected in a significantly lower carotene content of the milk from the urea-fed cows as compared with the control group. However, Rupel et al (8) noted that the mixing of urea with a concentrate mixture fed to lactating cows did not affect the vitamin A content of the milk. Since Wise et al fed the same concentrate mixture to the groups receiving both urea-treated and untreated silage, there was no way of determining whether or not the nitrogen of the urea fed this way was utilized or not. Further research on the usefulness and palatability of urea-treated silage is indicated.

Recently there have been some feeding trials carried out to test the value of ammoniated sugar beet pulp as a feed for ruminants. H. C. Millar (5) of the Quaker Oats Research Laboratories describes such an experiment. He prepared an ammoniated pulp by adding 15 pounds of ammonia to 300 pounds of pulp and revolving the mixture in a closed unit for 30 minutes. Millar does not state why nitrogen in the form of ammonia was used, It is possible that the ammonia formed a

chemical combination with some component of the beet pulp.

The final product contained 25 to 27% protein (N x 6.25) and this could be mixed with plain pulp to produce a mixture of any desired protein content. Millar used calves to compare the growth-promoting qualities of a basal ration of 7% protein with various rations containing ammoniated beet pulp and having protein equivalent ranging from 12 to 17%. He found that a ration of 12% protein was equal to one of 17% with respect to growth, although growth was unsatisfactory with the basal ration. A ration in which toasted soybean meal was used to bring the protein content of the ration up to 16.5% was found to give the best growth. It was concluded that the nitrogen of ammoniated beet pulp can be used by ruminants for purposes of growth. Millar suggests that the soybean meal was superior to the ammoniated beet pulp because it contained more of the essential amino acids than did the protein synthesized from the ammonia. To correct this, it was suggested that a fairly large variety of feeds be used in conjunction with the ammoniated pulp to reduce the possibility of protein quality's being a limiting factor. This seems to point to the fact that more research is needed with respect to the feeding of ammoniated pulp.

Johnson et al (4) conducted metabolism experiments with sixteen growing lambs, to compare the biological utilization of the nitrogen from urea, soybean meal, and casein. They used a basal ration containing about 6% protein and made up of corn and red top hay. The urea, soybean meal, and casein

were added to the basal to make up rations of different nitrogen levels. It was found that the lambs made fairly satisfactory gains on a ration to which urea had been added to bring the protein level up to 12%, but that the addition of further amounts of urea did not improve the ration. They concluded that urea was utilized to a certain extent but that it was not converted rapidly enough to protein to meet the requirements of growing lambs. In general, the urea protein was as well utilized in metabolism as soybean protein, and somewhat better than casein protein.

Harris and Mitchell (2) fed lambs a low protein basal ration that by itself could not maintain nitrogen equilibrium. To this ration they added urea to bring the protein content up to 11% (N x 6.25), the urea providing about 50% of the nitrogen. They state that the urea ration was capable of promoting normal or nearly normal growth in lambs.

The experiments reviewed here indicate that urea was fairly effectively utilized by ruminants up to a certain level. Higher levels did not seem to be so well utilized, possibly owing to a limited capacity to convert urea to protein. There is some evidence that sheep have a high requirement for sulphur-containing amino acids because of their heavy growth of wool, and it may not be possible for the micro-organisms of the rumen to synthesize sulphur-containing amino acids. In general urea appears to be used as a substitute for standard protein supplements,

although it does not appear to be quite on a par with standard supplements for purposes of growth and milk production.

Conversion of Urea

There has naturally been a good deal of interest in the changes undergone by urea during its conversion to protein in the rumen. Using a fistulated heifer, Wegner et al (11) found that within one hour after the ingestion of a ration containing urea, the urea had been converted to ammonia. Within four to six hours after ingestion the nitrogen of the ration was all in the form of protein nitrogen.

By using the juices squeezed from the rumen contents of a cow, these workers were able to make an in vitro study of the conversion of urea to protein (10). Some of the urea-containing ration was mixed with this liquid, incubated at 37°C. temperature and a carefully regulated pH, in order to simulate as nearly as possible the normal conditions encountered in the rumen. These in vitro studies yielded essentially the same results as did the in vivo studies with the fistulated heifer, in that urea was converted to ammonia nitrogen and this, in turn, was converted to protein nitrogen. It appears from this that the conversion of simple nitrogenous compounds to protein is effected by micro-organisms found in the rumen, and that these proteins are built up into the bodies of the micro-organisms. The bodies of these are then probably broken down

in the abomasum (true stomach) and later absorbed from the small intestine of the ruminant.

Smith and Baker (9) in Scotland have given some study to the question of what micro-organisms are concerned with the conversion of urea to protein. Juices were taken from rumen contents and, by means of centrifuging, it was possible to separate this juice into fractions one of which contained bacteria and the other protozoa. When feed containing urea was added to both fractions it was found that the bacteria were able to convert the urea to protein, whereas the protozoa were unable to do so. After the bacteria had converted the urea they were precipitated, dried, and analyzed. This precipitate was found to be 36.3% protein, 46.6% polysaccharide, 9.5% fat, and 6.2% ash, which corresponds quite closely to the analysis of common protein supplements such as linseed meal. Research in the quality of protein from such a precipitate would provide very valuable information with regard to the value and possible limitations of urea as a substitute for common protein supplements.

The effect of the level of protein in the ration on the conversion of urea to protein has been given some study. Wegner et al (12) at Wisconsin fed rations with various protein levels to a fistulated heifer. A basal concentrate mixture with 12% protein was used. To this basal concentrate mixture various amounts of linseed meal or urea or both were added to increase the protein content of the ration as a whole.

When the ration contained 12% of preformed protein, the urea nitrogen was converted to ammonia nitrogen within one hour after ingestion, and this in turn was converted to protein nitrogen within four to six hours. When the protein content ranged from 12 to 18%, the rate of conversion was lowered, although the extent of conversion was not. When protein was over 18%, both the rate and extent of conversion were lowered. Apparently urea is utilized to the maximum only when the protein content of the ration is of moderate level.

An experiment has been conducted by Mills et al (6) to ascertain the effect of starch on the conversion of urea. A fistulated heifer was given a ration of timothy hay alone with urea added. The conversion of urea could not be demonstrated in this case and apparently the urea was not utilized.

The heifer was then given the same ration, to which four pounds of starch were added daily. In this case it was found that the percentage of protein in the rumen contents was increased from 6.8% to 10.7%, or an increase of 57%. Apparently urea can only be utilized at a maximum rate and efficiency in the presence of an adequate supply of readily fermentable carbohydrate.

These same workers also tested the effect of supplying carbohydrate in the form of molasses, but found that this did not stimulate the conversion of urea. They concluded that the molasses, being very soluble, passed out of the rumen before the other components of the ration and was therefore not available to supply energy to rumen bacteria that convert

urea to protein. In an in vitro experiment with rumen bacteria Pearson and Smith (7) found that starch was more effective in promoting the conversion of urea than any of glucose, glycerol, or lactic acid. This seems to indicate that some factor in addition to that postulated by Mills et al (6) may be responsible for the greater effectiveness of starch in promoting the conversion of urea.

A brief review has been given, indicating that it is possible, by the symbiotic relationship of rumen bacteria, for ruminant animals to utilize urea as a protein supplement and satisfy their nutritive requirements to a certain extent. The mechanism whereby urea may be converted to protein has been given some study but further research is indicated. As has been shown, certain factors will influence the rate and extent of the conversion of urea to protein, such as the presence of starch and the level of protein in the ration. These factors need to be considered when rations containing urea are being designed.

Considering that urea can undoubtedly be used to advantage in rations for ruminants it was felt that a trial to determine the value of urea as a substitute for protein supplements should be carried out under Alberta feeding conditions. Two experiments were conducted with lactating cows and two with pregnant ewes during the winters of 1943-4 and 1944-5, and are herein reported. These experiments were made possible by a grant from the Consolidated Mining and Smelting Company of Canada, Limited.

OUTLINE OF FEEDING TRIAL WITH DAIRY COWS FOR 1943-4

Plan of the Experiment

Only four pairs of cows suitable for the experiment were available. It was possible to match the cows evenly for breed, milk flow, and stage of lactation, but it was not possible to match them evenly for butterfat test. The cows were paired as follows:

	Urea	Linseed meal
Cow number	1	2
" "	3	4
" "	5	6
" "	7	8

so that odd-numbered cows were fed urea and even-numbered cows fed linseed meal. Two pairs of the cows were fed experimentally for 14 consecutive weeks and the other two pairs for 9 and 7 weeks, respectively. One of each pair was fed the normal ration containing a sufficient quantity of the natural protein supplements, and the other cow of each pair a ration in which all of the linseed meal and a small part of the wheat bran were replaced by urea. In the urea ration enough carbonaceous concentrates were added to give it practically the same percentage of total digestible nutrients as that of the linseed meal ration. The substitution of urea for linseed meal was made on the basis of nitrogen content.

The following table indicates the proportion of constituents used in the different rations; the percent T.D.N. was based on Morrison's feeding standards and the percent nitrogen was found by analysis.

TABLE III

Components of rations for dairy cows

	Normal ration, lb.	TDN,%	N, %	TDN,lb.	N,lb.
		Lot I			
Wheat bran	400	70.2	2.68	281	10.7
Oats	800	71.5	1.53	572	12.2
Barley	200	78.7	1.95	157	3.9
Linseed meal	600	78.2	4.73	469	28.4
	2000			1479	55.2
				74%	
Protein equivalent ..... 345 lb.					
Protein equivalent 17.2%					
		Lot II			
	Urea ration				
Wheat bran	390	70.2	2.68	274	10.5
Oats	1249	71.5	1.53	893	19.1
Barley	312	78.7	1.95	246	6.0
Urea	49		44.90		22.0
	2000			1413	57.6
				70.6%	
Protein equivalent ..... 360 lb.					
Protein equivalent 18%					

With regard to roughage the cows were supplied with as much hay and oat silage as they would readily consume. The

hay was of medium quality and consisted of a mixture of timothy and alfalfa hay, and the silage, made from green cut oats, was of excellent quality.

The composition of these roughages is as follows, the T.D.N. being based on Morrison's feeding standards:

	TDN, %	N, %	DCP, %
Timothy x alfalfa	47.9	1.2	3.84
Oat silage	22.0	.35	1.31

For D.C.P. the digestible coefficients from Morrison's tables were used. The concentrate mixtures mentioned above were used from the beginning of the experiment on December 22, 1943, until February 16, 1944. At this time, it was found that, in view of the natural decline in the rate of milk flow of the cows, this concentrate mixture provided more protein than was required. The concentrate mixture was therefore changed to the following:

TABLE IV

Components of rations for dairy cows

	Normal ration, lb.	TDN,%	N, %	TDN,lb.	N,lb.
		Lot I			
Wheat bran	400	70.2	2.68	281	10.7
Oats	900	71.5	1.53	643	13.8
Barley	220	78.7	1.95	172	4.3
Linseed meal	480	78.2	4.73	375	22.7
	2000			1471	51.5
				73.5%	
Protein equivalent ..... 322 lb.					
Protein equivalent 16.1%					
		Lot II			
	Urea ration				
Wheat bran	400	70.2	2.68	281	10.7
Oats	1260	71.5	1.53	901	19.4
Barley	300	78.7	1.95	236	5.8
Urea	40	78.2	44.90	-	18.0
	2000			1418	53.9
				70.9%	
Protein equivalent ..... 338 lb.					
Protein equivalent 16.9%					

The cows were weighed each week and a continuous record was kept of milk and fat production. Using these data the cows were fed in accordance with their requirements as stated by Morrison.

Results

Data were recorded to permit a comparison of the

urea and the linseed meal rations in the following respects:

1. Quantity of milk produced.
2. Percent butterfat of the milk.
3. Changes in body weight.
4. Palatability of the two rations.

Quantity of Milk Produced

The performance of the cows with regard to milk and butterfat production is presented in Table V as follows:

TABLE V

Production performance

	Cow	Weeks on test	lb. Total milk	Average test	lb. Total fat	lb. Total F.C.M.	% decline during test milk	% decline during test F.C.M.
				Group I				
Urea	1	14	4481.0	2.64	118.6	3571.2	39.8	45.3
	3	14	3569.0	2.65	94.6	2846.6	8.9	10.5
	5	9	2396.9	3.10	74.1	2070.6	17.1	15.9
	7	7	1303.0	5.17	67.6	1540.6	20.4	20.2
Total			11749.9		354.9	10029.0		
Average fat test				3.02				
				Group II				
Linseed meal	2	14	4750.2	3.11	147.7	4118.6	29.0	31.3
	4	14	2989.4	3.00	90.1	2544.5	16.3	13.0
	6	9	2605.5	3.87	98.9	2526.6	15.3	7.5
	8	7	1498.6	5.54	83.1	1846.0	19.9	13.7
Total			11843.7			11035.7		
Average fat test				3.54				

It may be noted that the total milk production of cows fed linseed meal was only 0.80% more than for the cows on the urea ration. The difference is so small that it may be considered as of no significance. During the period on trial there was a decline of 23.7% in the total milk production of the cows on urea, whereas in the case of the linseed-meal-fed group there was a decline of 21.1%. Considering that only four pairs of cows were used and that there may have been some differences in the natural persistency of milk flow, this small difference in milk production or percentage decline cannot be attributed to differences in the rations. Apparently the urea ration was equal to the linseed meal ration with regard to maintaining milk flow.

Percent Butterfat of the Milk

Although the difference in total milk produced by the two groups of cows was slight, the average butterfat percentage of milk from the urea-fed cows was definitely lower than for the linseed-meal-fed cows. This may have been due to naturally lower? higher testing cows having been allotted to the urea ration. ? It may be noted in Table VI that the initial fat percent for the cows fed urea was lower than that of the cows fed linseed meal. It may be significant that the Records of Performance for the previous year indicate that the urea-fed cows normally had a lower fat percent than the linseed-meal-fed cows.

TABLE VI

Butterfat test for the cows during the trial

	Urea ration				Linseed meal ration			
	Cow				Cow			
Week	1	3	5	7	2	4	6	8
1	2.9	2.7	3.0	6.0	3.5	3.0	3.6	5.2
2	2.8	2.6	3.0	6.0	3.0	3.0	3.6	5.6
3	2.6	2.8	3.5	4.8	3.0	2.7	3.6	5.8
4	2.5	2.7	2.9	4.7	3.1	3.0	3.4	6.0
5	2.6	2.6	3.0	4.8	3.2	3.0	3.6	5.8
6	2.7	2.9	3.1	4.9	3.3	3.2	4.3	4.6
7	2.2	2.6	3.2	5.0	3.0	2.7	3.8	5.8
Av.	2.61	2.70	3.10	5.17	3.16	2.94	3.70	5.54
ROP previous year	3.15	3.00	3.59	N.R.*	3.70	3.87	4.11	6.82

* No previous record.

It will be noted that there was a tendency for the fat percent of the milk from the urea-fed cows to drop more markedly than the fat percent of the milk from the linseed-meal-fed cows. For the first week the average fat percent of milk of the urea-fed cows was 3.4%, while that of the linseed-meal-fed cows was 3.8%. At the end of seven weeks the fat percent was 3.0% and 3.7%, respectively, indicating that there was a marked drop in the fat percent of milk from the urea-fed cows.

The greater drop in percent fat by the urea-fed cows was reflected in a slight drop in the production of F.C.M. for the urea-fed group, as shown in Table V. The urea-fed group

produced 10029.0 lb. of 4% F.C.M. during the period of trial, whereas the linseed-meal-fed group produced a total of 11035.7 lb., or 10.0% more than the urea-fed group. During the period of the trial the urea-fed group showed a slightly more rapid decline in the production of F.C.M. than did the linseed-meal-fed group. In view of the small number of cows used, this difference is not considered to be significant.

Changes in Body Weight

Both groups of cows made similar gains in body weight; the urea-fed cows gained a total of 123 lb. and the linseed-meal-fed cows gained 117 lb. For the maintenance of body weight the two rations appear to have been the same.

Palatability of the Rations Compared

There was evidence that the urea ration was not as palatable as the linseed meal ration when fed to dairy cows.

The first two cows started on the urea ration (No.1 and No.3) ate their ration very slowly as compared with No.2 and No.4, receiving the linseed meal ration. Even after the urea of the grain mixture was reduced from 60 lb. to 49 lb. the cows continued to eat it very slowly.

The fact that the urea grain mixture contained small pebbles of urea suggested that possibly the presence of these pebbles caused the mixture to be less palatable to the cows. The urea was therefore sifted through a fine screen immediately prior to its being mixed in the grain. This practice appeared

to improve the palatability of the urea ration to some extent, but it was still not as palatable as the linseed meal ration.

Cows No.5 and No.6 were put on the feeding trial five weeks after the other two pairs of cows were started. Cow No.5 received the urea ration and, while she did not eat it as readily as she had previously been eating the normal herd grain mixture supplied to the non-experimental animals in the barn, she always consumed her ration eventually. Cow No.6, fed the linseed meal ration, showed a good deal of reluctance with regard to eating the grain mixture provided. The only explanation of this seems to lie in the statement of the stable foreman that this individual animal had always been very discriminating with regard to her feed and that even a slight change tended to "put her off her feed".

In the case of cows No.7 and No.8, No.8 was started on the urea ration. After five weeks on the urea ration she refused the grain mixture almost entirely and began to lose weight rapidly. Within five weeks her weight had dropped from 848 lb. to 780 lb., or a drop of 68 lb. (8%), and her production dropped from 35 lb. of 6% milk per day to 29.7 lb. of 5.5% milk. Her condition became what might be termed critical. It was found necessary, therefore, to switch cow No.8 to the linseed meal ration and put cow No.7 on the urea ration. After being switched to the linseed meal ration, cow No.8 showed an immediate improvement in general appearance, gained weight rapidly, and showed a slight gain in milk and fat production. Cow No.7 accepted the urea ration, but not as readily as she

had the linseed meal ration. The data for these two cows were considered only from the time when the change in the ration was made. It would appear from these experiences that urea may be sufficiently distasteful to some cows to lower the consumption of grain mixtures containing it below the requirement level of the cow.

Discussion

The results of this feeding trial indicate that the use of urea as a substitute for standard protein supplements did not affect the total milk production of lactating dairy cows. This confirms experiments at Wisconsin (1) (8). On the other hand, the production of fat and fat-corrected milk were both markedly lowered. In other words, urea was not as effective as linseed meal for the maintenance of fat and fat-corrected milk. In the results published by other workers no reduction in fat or F.C.M. caused by urea feeding was found. When it is considered that most of the cows used in this experiment were heavy producers and therefore needed to consume fairly large quantities of urea, it is possible that the quantities of urea in the urea ration were too large to be converted efficiently.

With regard to the possible conversion of urea to protein by these cows, some data may be considered that may throw a little light on the question. The cows fed the linseed meal ration consumed 0.53 lb. daily, of which 0.11 lb. (Or 20%) was urea nitrogen. Even assuming a 100% conversion

and assimilation of urea nitrogen, the urea-fed cows consumed only 7% in excess of their requirements of digestible protein. These results indicate that some of the urea nitrogen must have been utilized since the remaining 0.44 lb. of nitrogen would not have been sufficient to meet the minimum requirements of the cows.

It would appear from the results that the lower palatability of the urea rations will limit its commercial use unless some means of overcoming its unpalatability can be devised. It is possible that lower levels of urea in the grain mixture than were used in this feeding trial (49 lb. per ton) would give better results.

Conclusions

1. Urea was found to be utilized by lactating cows as a substitute for linseed meal.

2. Milk production was not affected when urea was substituted for linseed meal in the ration of lactating cows.

3. Fat production may have been affected by the feeding of urea, but additional data are needed to verify this.

4. Considerable evidence was obtained indicating that urea as fed in this experiment was unpalatable to some of the cows, and resulted in their failure to consume their grain allowance readily.

OUTLINE OF FEEDING TRIAL WITH DAIRY COWS FOR 1944-5

The data obtained in the 1943-4 feeding trial were considered insufficient to provide conclusive evidence for determining the effect of substituting urea for linseed meal as a protein supplement for lactating cows. It was therefore deemed advisable to conduct a second trial, in an attempt to throw more light on the question of palatability of urea-containing mixtures and also their possible effect on the butterfat percent of lactating cows, as well as securing more data on the effect of urea on milk production. Consequently, in the fall of 1944, an experiment was again designed to determine the effect of urea as a protein supplement on the body weight, milk and fat production of lactating cows.

Plan of the Experiment

A total of fourteen cows were used in this feeding trial, of which all were Holsteins except numbers 10, 11, and 12, which were Jerseys. Three rations were fed, differing only in the kind of protein supplement used in the grain mixture. These rations will be designated as follows:

1. Urea ration
2. Linseed meal and urea ration
3. Linseed meal ration.

In the urea ration all the linseed meal was replaced by urea and carbonaceous grains, while in the urea + linseed meal ration half the linseed meal was replaced in this way.

The following are the proportions of different ingredients used in the grain mixtures:

TABLE VII

Grain mixtures for 1944-5 feeding trial

	lb.	TDN,%	N, %	TDN,lb.	N,lb.
		Urea ration			
Bran	400	71.0	2.97	284.0	11.9
Oats	1160	71.5	1.81	830.0	21.0
Barley	400	78.7	1.64	314.6	6.7
Urea	40		46.00	--	18.4
	2000			1428.6	58.0
				71.43%	
Protein equivalent ..... 362 lb.					
Protein equivalent 18.10%					
		Urea and linseed meal ration			
Bran	400	71.0	2.97	284.0	11.9
Oats	1030	71.5	1.81	737.0	18.6
Barley	400	78.7	1.64	314.6	6.6
Linseed meal	150	78.4	4.25	117.6	6.4
Urea	20		46.00	--	9.2
	2000			1453.2	52.7
				72.66%	
Protein equivalent ..... 328.8 lb.					
Protein equivalent 16.44%					
		Linseed meal ration			
Bran	400	71.0	2.97	284.0	11.9
Oats	900	71.5	1.81	644.0	16.2
Barley	400	78.7	1.64	314.6	6.6
Linseed meal	300	78.4	4.25	235.0	12.8
	2000			1477.6	47.5
				73.88%	
Protein equivalent ..... 296.0 lb.					
Protein equivalent 14.80%					

The values of total digestible nutrients (TDN) were taken from Morrison's Feeding Standards and the values for N, % were determined by analysis. In the urea ration and urea + linseed meal ration enough carbonaceous concentrates were added to give them practically the same percentage of T.D.N. as the linseed meal ration. The substitution of urea for linseed meal was made on the basis of nitrogen content.

The cows were supplied with as much hay and oat silage as they would readily consume. The hay was of medium quality and consisted of a mixture of timothy and oat hay, and the silage, made of green cut oats, was of excellent quality.

The composition of these roughages is as follows, the T.D.N. being based on Morrison's Feeding Standards:

	TDN,%	N, %	Protein equivalent
Timothy x oat hay	46.6	1.22	7.62
Silage	16.3	0.38	2.38

The protein equivalent was taken as N x 6.25.

The cows were allotted to the different rations for different periods of time as shown in Table VIII. The numbers under the rations fed refer to individual cows.

TABLE VIII

Allotment of cows to the rations

No. weeks in period	Urea ration	Urea + linseed meal ration	Linseed meal
7	1		2
6	3	4	5
7	5	4	3
5	3	4	5
2		6*	7
5	7	8	9
1	10+		11
7		10	11
5	12*(1 wk.)	11	10
8		13	14

* Refused grain mixture and was removed from the experiment.

\+ Refused the urea mixture and was transferred to the linseed meal + meal mixture.

It may be noted that five sets each containing either 2 or 3 cows were used. When placed on the trial, the cows of each set were equal as far as possible with respect to breed, stage of lactation, milk flow, and body weight.

The cows were weighed each week and a continuous record was kept of the milk production and fat percent. Using these data, cows were fed in accordance with their requirements, as stated by Morrison.

Results

It was assumed in this experiment, as in the previous experiment, that the comparative values of the different protein supplements would be indicated by differences in performance of the three groups in the following respects:

1. Quantity of milk produced.
2. Production of fat and fat-corrected milk (F.C.M.).
3. Changes in body weight.
4. Palatability of the rations.

In this experiment it was possible to make comparisons of the three rations:

1. Urea ration vs linseed meal ration.
2. Urea ration vs linseed meal + urea ration.
3. Linseed meal + urea ration vs linseed meal ration.

Comparisons for these groups are made in the tables IX, X, and XI, indicating production performance.

TABLE IX

Production performance of groups 1 and 2

	No. of cow	No. of weeks	Milk, lb. First week	Milk, lb. Total	Total fat	F.C.M., lb. 1st week	F.C.M., lb. Total	Av. fat test	% decline In milk Total	% decline In milk Per week	% decline In F.C.M. Total	% decline In F.C.M. Per week	Gain in weight
Group 1													
Linseed meal ration	2	7	126.8	747.0	40.6	160.2	907.8	5.43	35.5	5.07	35.6	5.09	-2
	5	6	359.6	2006.0	57.2	305.8	1768.4	2.85	15.4	2.57	15.6	2.60	+2
	3	7	343.8	2229.8	67.9	292.0	1910.4	3.05	13.3	1.90	11.4	1.63	+15
	5	5	271.9	1344.5	35.0	218.3	1062.8	2.60	2.2	.44	3.9	.78	-38
	9	5	467.5	2041.8	67.8	454.0	1833.7	3.32	20.9	4.22	33.4	6.68	+53
Total			1569.6	8369.1	268.5	1430.3	7483.1						+30
Average								3.21		2.84		3.36	+6
Group 2													
Urea ration	1	7	118.0	720.2	45.5	158.2	970.6	6.32	24.4	3.68	25.3	3.61	-5
	3	6	414.0	2322.9	75.7	374.1	2064.4	3.26	11.0	1.83	16.8	2.80	-80
	5	7	287.9	1935.5	53.8	232.2	1581.2	2.78	5.4	.77	5.3	.76	-2
	3	5	284.1	1405.9	44.8	250.1	1234.4	3.19	1.8	.36	3.2	.64	+17
	7	5	380.0	1876.7	52.2	311.0	1533.7	2.78	2.5	.50	2.2	.44	+17
Total			1484.0	8261.2	272.0	1325.6	7384.3						-3
Average								3.29		1.43		1.65	-0.6

Group 1 exceeds Group 2 by:

	85.6	107.9	104.7	98.8 (lb.)
	5.77	1.31	7.90	1.34 (%)

TABLE X

Production performance of groups 3 and 4

	No. of cow	No. of weeks	Milk, lb. First week	Milk, lb. Total	Total	F.C.M., lb. 1st week	F.C.M., lb. Total	Av. fat test	% decline In milk Total	% decline In milk Per week	% decline In F.C.M. Total	% decline In F.C.M. Per week	Gain in weight
Group 3													
Urea ration	3	6	414.0	2322.9	75.7	374.1	2064.4	3.26	11.0	1.83	16.8	2.80	-80
	5	7	287.9	1935.5	53.8	232.2	1581.2	2.78	5.4	.77	5.3	.76	-2
	3	5	284.1	1405.9	44.8	250.1	1234.4	3.19	1.8	.36	3.2	.64	+17
	7	5	380.0	1876.7	52.2	311.0	1533.7	2.78	2.5	.50	2.2	.44	+67
Total			1366.0	7541.0	226.5	1167.4	6413.7						-2
Average								3.00		.86		1.16	-0.5
Group 4													
Linseed meal	4	6	349.2	1915.5	58.8	297.2	1648.2	3.07	12.6	2.10	12.5	2.08	-78
+	4	7	291.0	1999.6	59.0	246.9	1684.8	2.95	4.8	.69	4.7	.67	-35
Urea ration	4	5	269.9	1318.6	37.5	229.5	1090.1	2.84	4.8	.96	10.1	2.02	-4
	8	5	424.0	2099.3	68.4	380.2	1865.7	3.26	1.6	.32	3.1	.62	-1
Total			1334.1	7333.3	223.7	1153.8	6288.8						-118
Average								3.05		1.02		1.35	-29.5

Group 3 exceeds Group 4 by:

31.9	207.7	13.6	124.9 (lb.)
2.39	2.83	1.18	1.99 (%)

TABLE XI

Production performance of groups 5 and 6

	No. of cow	No. of weeks	Milk, lb. First week	Milk, lb. Total	Total fat	F.C.M., lb. 1st week	F.C.M., lb. Total	Av. fat test	% decline In milk Total	% decline In milk Per week	% decline In F.C.M. Total	% decline In F.C.M. Per week	Gain in weight
Group 5													
Linseed meal	4	6	349.2	1915.5	58.8	297.2	1648.2	2.85	12.6	2.10	12.5	2.08	-75
+	4	7	291.0	1999.6	59.0	246.9	1684.8	3.05	4.8	.69	4.7	.67	-35
urea ration	4	5	269.9	1318.9	37.5	229.5	1090.1	2.60	4.8	.96	10.1	2.02	-4
	8	5	425.4	2099.3	68.4	380.2	1865.7	3.32	1.6	.32	3.1	.62	-1
	10	7	268.1	1700.5	72.3	281.2	1764.7	6.09	15.5	2.21	15.5	2.21	-23
	11	5	184.4	926.1	56.9	253.9	1223.9	4.04	3.0	.60	6.2	1.24	+13
	13	8	294.6	2245.5	74.3	258.8	2012.7	3.14	6.1	.76	-7.1	-.89	-2
Total			2082.6	12205.4	427.2	1947.7	11290.1						-130
Average								3.56		1.09		1.14	-18.6
Group 6													
Linseed meal	5	6	359.6	2006.0	57.2	305.8	1768.4	3.07	15.4	2.57	15.6	2.60	+2
	3	7	343.8	2229.8	67.9	292.0	1910.4	2.95	13.3	1.90	11.4	1.63	+15
ration	5	5	271.9	1344.5	35.0	218.3	1062.8	2.84	2.2	.44	3.9	.78	-38
	9	5	467.5	2041.8	67.8	454.0	1833.7	3.26	20.9	4.22	33.4	6.68	+53
	11	7	268.2	1669.8	101.7	360.8	2193.4	4.25	19.0	2.71	21.8	3.11	-4
	10	5	214.6	1024.7	47.5	228.3	1122.3	6.14	7.7	1.54	1.6	.32	+12
	14	8	284.1	2252.7	70.7	259.1	1961.6	3.31	0.8	.10	7.3	.91	+18
Total			2209.7	12569.3	447.8	2118.3	11852.6						+58
Average								3.50		1.85		2.29	+8.3
Group 6 exceeds Group 5 by:			127.1	363.9	20.6	170.6	562.5	(lb.)					
			6.10	2.98	4.82	8.76	4.98	(%)					

Quantity of Milk Produced

Urea ration vs linseed meal ration

In comparing linseed meal (Group 1) with urea (Group 2) it may be noted that the linseed-meal-fed group produced 1.31% more milk than did the urea-fed group. This greater amount of milk was due in part to the fact that the cows on the linseed meal ration were producing 5.77% more milk than those on the urea ration when the experiment started. This initial advantage does not appear to have been maintained since the cows on the linseed meal ration declined more rapidly in milk flow than did the cows on the urea ration. The average percent decline per week was 2.84% for the linseed-meal-fed group and 1.43% for the urea-fed group. It would appear, therefore, that urea was equal to linseed meal for purposes of maintaining the production of milk in lactating cows.

Urea ration vs linseed meal + urea ration

A similar comparison may be made between the urea ration and the linseed meal + urea ration. In this case, the urea-fed group produced 2.83% more milk than did the urea + linseed-meal-fed group. The initial production in the case of the urea-fed group was 2.39% more than for the urea + linseed-meal-fed group, and the average percent decline per week was 0.86% for the urea-fed group and 1.02% for the urea + linseed-meal-fed group.

There does not appear to be any difference between the urea ration and the linseed meal + urea ration from the standpoint of the maintenance of milk production.

Linseed meal ration vs urea + linseed meal ration

In this case the cows fed linseed meal produced a total of 2.98% more milk than the cows fed the urea + linseed meal ration. Here again the greater amount of milk was due in part to the fact that the cows on the linseed meal ration were producing 6.1% more milk than the cows on the urea + linseed meal ration when the experiment started. This initial advantage does not appear to have been fully maintained during the trial since the decline in milk flow was 1.85% per week for the linseed-meal-fed group and 1.09% per week for the urea + linseed-meal-fed group. It would therefore appear that the urea + linseed meal ration was fully as effective as the linseed meal ration with regard to maintaining the level of milk production in lactating cows.

In general, it appears that the substitution of urea for all or part of the linseed meal in the grain mixtures fed to lactating cows had no discernible effect on the milk production of cows.

Production of Fat and F.C.M.

It will be noted in the tables for production performance for the various groups that the differences in the

average fat percent of milk for the different groups were so slight that they may be considered as negligible. As a result of this similarity in average fat test for the comparable groups the F.C.M. comparisons have the same relationship as do the comparisons for total milk produced.

In general, it appears that the substitution of urea for all or part of the linseed meal in the grain mixture did not affect the fat production or production on the basis of F.C.M.

Changes in Body Weight

There did not appear to be any significant difference in average gain or loss in live weight of the cows in the different comparable groups, indicating that the rations containing urea were on a par with rations containing linseed meal, as far as the maintenance of live weight was concerned.

Palatability of the Rations

As was the case in the previous experiment, trouble was encountered with palatability of the grain mixtures containing urea. This trouble was encountered in spite of the fact that precautions were taken in this experiment that had not been taken in the previous experiment. The urea used in the second trial differed from that used in the first trial in that it was ground up to a very fine powder and treated so that no caking or lumping took place. It was possible, therefore, to obtain a thorough mixing of the urea in the grain

mixtures. This latter fact was demonstrated when five random samples were drawn from a one-ton lot of grain mixture containing 40 lb. of urea. Duplicate nitrogen analyses were run on these samples. It was found that the percent nitrogen varied from 2.81 to 2.84. This indicates that the urea was thoroughly and uniformly mixed with the grain.

The percentage of urea used in the grain mixtures was reduced from what had been used the former year. In the 1943-4 feeding trial levels of urea as high as 3% had been mixed with the grain. In the 1944-5 trial the urea mixture contained 2% urea, whereas the urea + linseed meal mixture contained only 1% urea.

In spite of these precautions the grain mixtures containing urea were always consumed more slowly by the cows than were grain mixtures in which the protein supplement was all in the form of linseed meal. In two cases cows refused urea mixtures entirely and had to be removed from the experiment. Cow No.6, fed the urea + linseed meal mixture, consumed it fairly well for two weeks and then refused it. This cow was then fed the linseed meal ration for two days and consumed it readily. The urea + linseed meal ration was then offered but was refused. Two days later this ration was again tried and again refused, at which time the cow was removed from the experiment. A similar experience was encountered with cow No.12 after the cow had been fed the urea ration for one week. This cow was also removed from the experiment. Cow No.10 refused the urea ration at the end of one week but, when

transferred to the urea + linseed meal ration, consumed what was offered, albeit rather reluctantly.

The palatability of the mixtures containing urea, when fed under conditions of this trial, was found to be a serious problem.

Discussion

The 1944-5 feeding trial conducted at the University of Alberta indicates that, from the standpoint of maintaining the production of milk in lactating cows, urea used as a protein supplement was on a par with linseed meal. These results confirm the results of the first trial conducted at the University of Alberta.

Fat percent was not affected by the use of urea as a protein supplement. This confirms the results of other workers (1) (8).

Palatability again proved to be a serious problem in spite of the fact that the percentage of urea in the grain mixtures had been reduced. In the topic, "Previous Literature" in this thesis, several tests were referred to in which urea mixed with grains was fed to lactating cows and to growing calves (1) (3) (8). In no case was any difficulty with palatability recorded. However, in one case (13) in which urea was mixed with silage, some difficulty with palatability was encountered. The experiment conducted at the University of

Alberta seems to be the only one to date indicating that urea included in a grain mixture is unpalatable to lactating cows. It is possible that the kinds of grain used in the feeding trial at the University of Alberta may have had some influence on the palatability. For example, in trials carried out at other stations, corn, hominy, molasses, and other feeds not common to Alberta were used in the grain mixtures. It is possible that the taste of the urea was more effectively masked by some of these ingredients, than it was in the grain rations used in this trial.

Further work is needed in order to study ways and means of overcoming the lack of palatability of rations containing urea.

Conclusions

1. In this second trial urea used as a protein supplement for lactating cows proved to be on a par with linseed meal from the standpoint of the production of milk, fat, and F.C.M., and for the maintenance of body weight.

2. Lack of palatability of urea-containing grain mixtures still proved to be a serious problem.

3. Further research to discover ways and means of making urea-containing grain mixtures more palatable to cows is indicated.

CONCLUSIONS FROM 1943-4-5 FEEDING TRIALS FOR COWS

1. The work at the University of Alberta has shown that urea mixed with grains up to the level of 40 lb. per ton (2%) and substituted for linseed meal on an equal nitrogen basis is as effective as linseed meal for purposes of maintaining the production of milk, F.C.M., and body weight.

2. Urea was found to be unpalatable to some cows when included in the grain mixture even at levels as low as 1%. The question of the palatability of urea rations is a problem that merits further study. Only when some solution is found to this problem can the commercial use of urea in dairy feeds be recommended.

FEEDING OF UREA AS A PROTEIN SUPPLEMENT TO PREGNANT EWES, 1943-1944

It has been shown as a result of feeding trials at the University of Alberta (Exp. 147, unpublished) that pregnant ewes require a fair proportion of protein in their ration. This protein can be satisfactorily supplied either in the form of a good legume hay or in the form of a supplement such as linseed meal, in cases where only low protein carbonaceous hays are available. The addition of one-half pound of grain daily to a ration of carbonaceous hay was found helpful, although even further improvement was effected if the same amount of a concentrate mixture of 2/3 grain and 1/3 linseed meal was provided. This last ration gave the best results with respect to maintenance of live weight of the ewes, as well as birth weight and general vitality of the lambs at the time of birth.

As has already been indicated in the review at the beginning of this thesis, sheep are capable of utilizing urea nitrogen. For this reason it was felt that an experiment should be conducted to ascertain the effectiveness of urea when substituted for linseed meal on the basis of nitrogen content, and with sufficient carbonaceous grains added to replace the T.D.N. of the linseed meal.

Plan of the Experiment

Three rations were used in this experiment: a basal ration of carbonaceous hays and grain; a similar ration except that linseed meal was included with the grains; and a ration containing urea as a substitute for linseed meal. The following proportions of feeds were used in the grain mixtures for the various rations:

TABLE XII

Grain mixtures fed

	lb.	TDN,%*	N ,%	TDN,lb.*	N , lb.
Lot 1 - basal ration					
Oats	980	71.5	1.53	700.7	15.0
Barley	980	78.7	1.95	771.3	19.1
Mono-calcium phosphate	40				
	2000			1472.0 73.6%	34.1
Protein equivalent					213.1 lb. 10.6%
Lot 2 - linseed meal ration					
Oats	653 1/3	71.5	1.53	467.1	10.0
Barley	653 1/3	78.7	1.95	514.2	12.7
Linseed meal	653 1/3	78.2	4.73	510.9	30.9
Mono-calcium phosphate	40				
	2000			1492.2 74.6%	53.6
Protein equivalent					335 lb. 16.8%

TABLE XII (continued)

	lb.	TDN,%*	N, %+	TDN,lb.	N, lb.
		Lot 3 - urea ration			
Oats	952 1/2	71.5	1.53	681.0	14.6
Barley	952 1/2	78.7	1.95	749.6	18.6
Urea	55		44.9		24.7
Mono-calcium phosphate	40				
	2000			1430.6	57.9
				7.15%	
Protein equivalent			361.9 lb.		
Protein equivalent			18.2%		

* Based on Morrison's Feeding Standards.
\+ Determined by analysis.

The nitrogen content of the hays, which were of fair quality, was 1.09% and .75% for the oat hay and prairie hay respectively.

The three lots were allowed continual access to common salt containing 0.25% potassium iodide and 0.025% cobalt chloride.

Three lots of seventeen ewes, similar with respect to breed, age, and weight, were started on the feeding trial in November, 1943. The average of weights obtained on three consecutive days was taken as the initial weight for each ewe and the ewes were weighed individually every two weeks in order that their progress could be checked as the experiment proceeded. The ewes were bred immediately after being placed on the experiment. The final recorded weight of the ewes prior to lambing was taken as the pre-lambing weight. The

post-lambing weight was obtained by weighing each ewe within eight hours after lambing.

Results

The following table shows the data obtained from the three lots of ewes:

TABLE XIII

Analysis of gains in body weight of the ewes

	Group 1 lb. Basal ration	Group 2 lb. Urea ration	Group 3 lb. L.O.M. ration
Total initial weight	2575.1	2500.5	2564.2
Average initial weight	151.5	147.1	150.1
Average gain to last pre-lambing weight	45.94	42.62	50.22
Minimum significant difference*	6.80	6.80	6.80
Average gain to post-lambing weight**	10.32	21.26	20.25
Minimum significant difference*	7.52	7.52	7.52

* Found by analysis of variance.

** Post-lambing weight taken within eight hours after lambing.

With regard to differences in gains between the initial and pre-lambing weights Group 2 on the urea ration made an average gain of 42.62 lb., whereas Group 3, fed the linseed meal ration, made an average gain of 50.22 lb. As the minimum significant difference was 6.80 lb., it may be

seen that the group on the urea ration made significantly lower gains than did Group 3. Since the pre-lambing weight is not considered to be a good criterion of the welfare of the ewe, not very much importance is attached to this latter fact. On the basal ration the gain between the initial and pre-lambing weight averaged 45.94 lb., a figure which did not differ significantly from those of either the urea or linseed meal rations.

Regarding differences between initial and post-lambing weights, Groups 2 and 3 made average gains of 21.26 lb. and 20.25 lb., respectively, whereas Group 1 (basal) made an average gain of 10.32 lb. The minimum significant difference in this case was 7.52 lb. It may be seen, therefore, that from the standpoint of producing and maintaining gains in body weight up until immediately after lambing, the urea and the linseed meal rations were equal to each other and superior to the basal ration.

It would seem logical to place a greater value on the gains made by the ewes between the start of the experiment and immediately after lambing, as the weights taken at these times represent the weights of "open" ewes, and gains that take place indicate gains in body tissues.

There was very little difference in the number of lambs produced by the ewes fed the different rations. Groups 1, 2, and 3 produced 28, 28, and 31 lambs, respectively. Con-

sidering that a ewe may produce from one to three lambs at birth, these differences in the number of lambs produced by the different groups may be neglected.

In considering the birth weight of the lambs it must be borne in mind that single lambs tend to weigh more at birth than do individual twin lambs, and that male lambs tend to weigh slightly more at birth than do female lambs. The average weight of these different classes of lambs is therefore given in the following table:

TABLE XIV
Average Birth
Weights of lambs - 1943-4 trial

Ration	No.*	Twin males	No.*	Twin Females	No.*	Single males	No.*	Single females
Basal	8	8.56	11	8.89	3	10.20	4	10.10
Urea	9	9.97	11	9.20	1	10.00	4	10.81
Linseed meal	15	9.49	8	7.92	2	10.10	4	10.81

* The number of lambs that make up the corresponding average weight.

In this table some of the lambs were not included. Those omitted had birth weights that were so low that it was felt that some factor other than the ration had influenced the birth weight.

While the number of lambs in the different groups is too low to provide representative averages, the tendency appeared to be for the ewes in the groups fed the urea and

linseed meal rations to produce heavier lambs. No explanation can be given to account for the low average weight (7.92 lb.) of the twin female lambs of the ewes fed the linseed meal ration. In previous trials at the University of Alberta it has been found that the use of linseed meal in the grain mixtures fed to pregnant ewes tended to increase the weight of the lambs dropped by these ewes, as compared with the weight of lambs from ewes fed grain without linseed meal.

In general, the results of the 1943-4 feeding trial with pregnant ewes do not allow for definite conclusions to be drawn with regard to the effect of the different rations fed to pregnant ewes on the birth weight of their lambs.

At the time of birth the live lambs were classified as weak, fairly strong, and strong, having reference mainly to the vitality of the lambs. These results are tabulated by percentages in Table XV.

TABLE XV

Vitality of the lambs at birth

	Basal ration	Urea ration	Linseed meal ration
% lambs born dead	14	7	0
% lambs born weak	11	4	3
% lambs born fairly strong	14	36	23
% lambs born strong	61	53	74

Lambs from the ewes fed the linseed meal ration had

97% of their lambs classified as either strong or fairly strong, whereas the corresponding figures for the urea and basal rations were 89% and 75%, respectively. There seems to be some indication that, from the standpoint of vitality of the lambs, linseed meal, when used as a protein supplement for pregnant ewes, was superior to urea and that urea in turn was superior to a ration which had no protein supplement.

The lambs produced during this experiment were dropped during the latter part of March and the early part of April, 1944. The percentage of lambs surviving on June 1st was 83 for urea-fed ewes, 75 for linseed-meal-fed ewes, and 65 for ewes on the basal ration. Considering that the feeding of the experimental rations to the ewes was discontinued at the time of lambing, it is not possible to attach much importance to these figures, although they do give a slight indication that the urea ration may cause ewes to produce more vigorous lambs than a low protein basal ration.

Palatability

The one-half pound of grain mixture fed daily was always consumed readily and no trouble was encountered with palatability of any of the rations.

Conclusions

In general it may be said that the feeding of urea

as a protein supplement to pregnant ewes proved beneficial in maintaining the live weight of the ewes. There appeared to be a tendency for the inclusion of urea in a low protein grain mixture to increase the birth weight of the lambs and reduce mortality slightly.

This first trial did not provide sufficient data and further work is required.

FEEDING UREA AS A PROTEIN SUPPLEMENT TO PREGNANT EWES, 1944-5

It was recommended as a result of the 1943-4 feeding trial that a further test should be conducted to confirm and, if possible, add to the information obtained. Consequently another feeding trial was initiated at the University of Alberta in the fall of 1944.

Plan of the Experiment

Four rations were used in this experiment: a basal ration of carbonaceous hays and grain; a similar ration except that linseed meal was included with the grains; a ration in which one-half of the linseed meal was replaced by urea on an equal nitrogen basis; and a ration in which all the linseed meal was replaced by urea. The following proportions of feeds were used in the grain mixtures for the various rations:

TABLE XVI

Grain mixtures fed

	lb.	TDN,%	N ,%	TDN,lb.	N ,lb.
		Lot 1 - basal ration			
Oats	980	71.5	1.81	700.7	17.74
Barley	980	78.7	1.64	771.3	16.08
M.C.P.*	40				
	2000			1472.0	34.82
				73.6%	
	Protein equivalent			217.6 lb.	
	Protein equivalent			10.88%	
		Lot 2 - linseed meal ration			
Oats	900	71.5	1.81	644.0	16.30
Barley	560	78.7	1.64	441.0	9.19
Linseed meal	500	78.4	6.81	392.0	34.05
M.C.P.*	40				
	2000			1477.0	59.54
				73.8%	
	Protein equivalent			372.0 lb.	
	Protein equivalent			18.60%	
		Lot 3 - urea + linseed meal ration			
Oats	924	71.5	1.81	661.0	16.73
Barley	750	78.7	1.64	590.0	12.31
L.M.	250	78.4	6.81	196.0	17.05
Urea	36		46.00		16.56
M.C.P.*	40				
	2000			1447.0	62.65
				72.4%	
	Protein equivalent			390.6 lb.	
	Protein equivalent			19.53%	
		Lot 4 - urea ration			
Oats	945	71.5	1.81	676.0	17.10
Barley	945	78.7	1.64	744.0	15.50
Urea	70		46.00		32.20
M.C.P.*	40				
	2000			1420.0	64.80
				71.0%	
	Protein equivalent			405.0 lb.	
	Protein equivalent			20.25%	

* Mono-calcium phosphate

The experiment started with four lots of twenty ewes, each similar with respect to breed, age, and weight. However, in the final analysis only the following numbers of ewes were considered:

Lot 1 - 14
" 2 - 18
" 3 - 16
" 4 - 16

This reduction in numbers was due to some ewes failing to prove in lamb and to some failing to prove in season.

The initial weight of the ewes was found by averaging the weights of the ewes for three consecutive days. The ewes were weighed every two weeks in order that their progress could be checked as the experiment proceeded. The ewes were bred immediately after being placed on the experiment. The weights recorded immediately prior to and within 8 hours after lambing were taken as the pre-lambing and post-lambing weights.

Results

When the gains in weight for the various groups are considered in conjunction with the corresponding minimum significant difference, it will be noted in Table XVII that the performance of the different groups with regard to gains in body weight is the same in all cases.

TABLE XVII

Analysis of gains in body weight of the ewes

(pounds)	Group 1 Basal ration	Group 2 Linseed meal ration	Group 3 Urea + linseed meal ration	Group 4 Urea ration
Number of ewes	15	19	17	16
Total initial weight	2076.8	2725.7	2421.6	2344.0
Av. initial weight	138.45	143.46	142.45	146.50
Av. gain to last pre-lambing weight	43.7	40.1	38.9	41.3
Min. significant dif.*	11.77	11.77	11.77	11.77
Av. gain to post-lambing weight+	20.9	17.2	18.4	20.8
Min. significant dif.*	7.53	7.53	7.53	7.53
Av. no. of lambs per ewe	1.47	1.32	1.29	1.69

* Found by analysis of variance.

+ Post-lambing weight taken within eight hours after lambing.

It appears from the results that the adding of protein supplements to the grain mixtures fed to pregnant ewes did not maintain the ewes in any better condition of flesh than did the basal ration of carbonaceous roughage and grain. These results contrast with those of the previous experiment in which, on the basis of the post-lambing weight, the basal ration was found to be inferior to both the urea and the linseed meal rations. This may be due in part to the fact that the ewes that went on to the 1944-5 feeding trial were in better condition at the start of the trial than were the ewes that went on to the 1943-4 feeding trial. It would be expected

that ewes in a high condition of flesh would give a poorer indication of the comparative values of low and high protein rations than would ewes in poor condition.

The difference in the number of lambs produced by the ewes fed the different rations was not considered to be significant. When we consider that each ewe may drop from one to three lambs, differences in the average number of lambs dropped per ewe, when only about 18 ewes per group are used, have to be very marked before they can be considered significant. Figures for the average number of lambs per ewe for the different groups are given in Table XVII.

These figures cannot be taken to indicate that any one ration is superior to any other ration with regard to the number of lambs produced at birth.

The average birth weight of the lambs was again calculated for twin male, twin female, single male, and single female, and these weights for the different classes of lambs are given in Table XVIII.

TABLE XVIII

Weights of lambs - 1944-5 trial

Ration	No.*	Twin males	No.*	Twin females	No.*	Single males	No.*	Single females
Basal	8	9.18	6	9.03	3	10.40	5	9.72
Linseed meal	5	9.40	5	8.68	6	11.01	6	10.70
Urea + linseed meal	5	9.98	6	8.10	4	12.75	7	10.61
Urea	6	8.85	14	8.60	3	11.17	2	11.70

* The number of lambs that make up the corresponding average weight.

The birth weights of a few of the lambs have been omitted in Table XVIII. These lambs had birth weights that were so low that it was felt that some factor other than the ration fed had influenced the birth weight.

There was considerable variation in the average lamb weights for the various groups. Numbers again were too small to establish representative averages. There was a tendency for the groups receiving a protein supplement to produce heavier lambs, except in the case of the twin lambs dropped by the urea-fed ewes as well as the female twin lambs dropped by the urea + linseed-meal- and the linseed-meal-fed ewes.

The inconclusive results obtained in the second trial may likewise be due to the more favorable feed conditions that prevailed prior to the experiment, which would tend to fortify the ewes against any deficiency which may have characterized the basal ration.

In general, the average birth weight of the lambs in the 1944-5 feeding trial does not allow for conclusions to be drawn with regard to the effect of the different rations fed to pregnant ewes, on the birth weight of the lambs.

At the time of birth the live lambs were classified as weak, fairly strong, and strong, having reference to the vitality of the lambs. These results are tabulated by percentages in Table XIX.

TABLE XIX

Vitality of the lambs at birth

	Basal ration	Linseed meal ration	Urea + linseed meal ration	Urea ration
% lambs born dead	4	4	0	0
% lambs born weak	9	12	9	15
% lambs born fairly strong	23	17	24	33
% lambs born strong	64	67	67	52
% fairly strong or strong	87	84	91	85

Here again the differences as shown in this table are not very marked, especially when we consider the total percentage of lambs classified as fairly strong and strong. There does not appear to be anything in these results to indicate that the vitality of the lambs was affected by any of the protein supplements fed to the ewes.

Palatability

The various grain mixtures fed to the ewes were always consumed readily and no trouble was encountered from lack of palatability.

Conclusions

In general it may be said that negative results were obtained in the 1944-5 feeding trial with pregnant ewes.

The feeding of protein supplements, whether in the form of linseed meal, urea, or both, did not affect the gains in body weight of the ewes or the weight or vitality of the lambs dropped by the ewes.

These results may also indicate that there is little or no need to add protein supplements to the ration of pregnant ewes when ewes commence pregnancy in a well nourished and vigorous condition.

CONCLUSIONS REGARDING THE USE OF UREA AS A PROTEIN SUPPLEMENT FOR RUMINANTS

The foregoing trials indicate that urea may be satisfactorily utilized by lactating cows as a protein supplement for the production of milk.

The problem of the lack of palatability of urea, when used in concentrate mixtures for cows, was not solved during these trials. Before urea can be recommended as a suitable dairy feed, ways and means must be found to overcome the lack of palatability.

Results of the feeding trials with pregnant ewes were not conclusive. It was not established that the inclusion of urea in grain mixtures fed to pregnant ewes was of any particular value if the ewes enter pregnancy in a thrifty condition of flesh, although some evidence pointed to the fact

that ewes entering pregnancy in an unthrifty condition would benefit by the inclusion of urea in their rations.

It is possible that growing lambs, which have a higher protein requirement than pregnant ewes, may give more favorable results if subjected to a urea feeding trial.

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